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1983/84 ST. CROIX RIVER WATER QUALITY REPORT

IWD-AR-WQB-84-68

INLAND WATERS DIRECTORATE
ATLANTIC REGION
WATER QUALITY BRANCH
MONCTON, NEW BRUNSWICK

1983/84 ST. CROIX RIVER

WATER QUALITY REPORT

IWD-AR-WQB-84-68

INLAND WATERS DIRECTORATE

ENVIRONMENT CANADA

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Atlantic Region

Moncton, New Brunswick

August 28, 1984

A copy will be made available in French upon request.

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LETTER OF TRANSMITTAL

Water Quality Branch
Inland Waters Directorate
Environment Canada
P. O. Box 861
Moncton, N. B.
August 28, 1984

Chairman, Canadian Section
IJC Pollution Advisory Board

Re: St. Croix River Water Quality Report 1983-84

This is the fourth annual report of the Water Quality of the St. Croix River, prepared by the Water Quality Branch.

The report concentrates on the Kellyland-Milltown portion of the river and incorporates data gathered from eight stations at approximately six week intervals.

Observations and comments on this report would be welcome.

Yours sincerely,

D. H. Cullen, Chief
Water Quality Branch

ABSTRACT

This report presents the results of the 1983-1984 St. Croix River water quality monitoring program. Physical parameter, major ion and heavy metal concentrations are presented for eight stations sampled on seven dates. The water quality at four of these stations is briefly discussed with reference to the effect of effluent loading from the Georgia-Pacific Pulp Mill at Woodland, Me.

RESUME

Ce rapport présente les résultats du programme de monitorage de la qualité des eaux de la rivière Ste-Croix pour 1983-1984. Les concentrations en ions majeurs, paramètres physiques et métaux lourds observées sont présentées pour chacunes des huit stations, échantillonnées en sept occasions. La qualité des eaux de quatre de ces stations est discutee brièvement en référence avec l'effet du débit de l'effluent de la Georgia-Pacific Pulp Mill à Woodland, Me.

INTRODUCTION

The Advisory Board on Pollution Control in the St. Croix River was established by the IJC in 1966 to co-ordinate water quality planning and management efforts in the basin by both the United States and Canada. To assist the board in fulfilling its mandate, the Water Quality Branch conducts regular water quality sampling in the International portion of the St. Croix to monitor the concentrations of toxic substances and other chemicals in the river water. The Water Quality Branch also participates in the development of water quality objectives with particular reference to the passage of Atlantic Salmon (Salmo salar).

This report presents the water quality data from eight stations sampled seven times during the period April 1983 to March 1984. Several previous WQB reports (M.S. report 1980; M.S. Report 1981, Howell & Lockerbie 1983) have discussed the water quality of the St. Croix River and thus extensive discussion of these data would be redundant. Therefore this report serves to present the current year's data along with a brief overview of water quality conditions at selected stations.

THE STUDY AREA

The study area is that part of the river which forms the international boundary between United States and Canada and represents a reach of approximately 124 km. In most of the drainage area and for the upper 110 km, the St. Croix River is considered to be pristine. It is the 14 km stretch between Woodland, Me. and Milltown, New Brunswick which is considered to be a water quality limited segment, even though it is now capable of supporting an anadramous run of Atlantic Salmon (Salmo salar). The problem in this reach is caused by a major industrial discharge from the Georgia-Pacific Kraft Pulp Mill at Woodland and to a lesser extent by municipal discharge and combined sewage outflows in Woodland and Baileyville, Me.

METHODS

The Water Quality Branch of Environment Canada sampled the St. Croix River on seven occasions during the 1983-1984 study period at eight stations located at Kellyland, Woodland, Baring and Milltown Figure 1). The Kellyland station is considered to be pristine and thus is indicative of background water quality conditions. The Woodland site is located near to the Georgia-Pacific Pulp Mill effluent outfall and serves to characterize the chemical composition of the effluent after slight dilution by river water. At Baring 8 km downstream from Woodland, samples were collected from stations located at mid-river and near the U.S.A. and Canadian shores. The Milltown site, 6 km below Baring was also sampled at mid-river and near the two shores. These six stations provide information not only on the rate of pulp mill effluent dilution but also on the horizontal homogeneity of the St. Croix River. Descriptions and NAQUADAT numbers of the eight water quality stations are presented in Table 1.

The Water Quality Branch sampling was conducted as outlined in the "Sampling for Water Quality" manual (WQB, 1983) and the analytical methods employed are described in the NAQUADAT Dictionary (WQB, 1983). A list of the selected water quality parameters, their NAQUADAT codes and detection limits are presented in Table 2. Daily mean discharge rates at Baring for the seven sampling dates are presented in Table 3.

RESULTS AND DISCUSSION

Kellyland - 00NB01AR0013

Physical measurements, major ion and heavy metal concentrations at Kellyland on seven dates are presented in Tables 4, 6 and 8 respectively.

The Kellyland station is located 15 km upstream from Woodland, Me. and is considered to be indicative of pristine water quality conditions. Water temperature during the study period varied between 0.5°C and 21.8°C and appeared to follow ambient air temperatures. Dissolved oxygen concentrations remained high throughout the entire year being very close to 100% saturation on all occasions. This was not expected, as moderately coloured waters are characteristically under-saturated with dissolved oxygen. However, water colours were low during the summer (10 to 20 Hazen Units) and reached moderate levels of 50 to 60 only during periods of high flow and increased loading of allochthonous organic matter. It is likely that high re-aeration rate and short residence time during periods of high stage maintained saturated conditions. In fact, as this station is located 1 km below the spillage of the Grand Falls a relatively high rate of aeration is to be expected.

The waters of the St. Croix River at Kellyland are extremely dilute with specific conductance ranging from 15 uS/cm to 33 uS/cm. The anions

are dominated by calcium (.149 to .179 meq/L) while the dominant cation is bicarbonate (.114 to .139 meq/L). Sodium and magnesium are found in nearly equal proportions with sodium generally being the second most abundant cation. Sulphate is the second most abundant anion, having concentrations (.073 - .104 meq/L) nearly double those of chloride (.036 to .062 meq/L). (Figure 2)

Most of the heavy metals are found below or near to the limit of detection. This is the case for lead, copper, cadmium and mercury. Values of chromium were occasionally above detection, but were well below the 0.05 mg/L guideline for drinking water supplies (McNeely et al., 1979). Iron and manganese concentrations showed little variation, having ranges of .10 to .18 mg/L and .01 to .03 mg/L respectively. Aluminum concentrations ranged from .03 to 0.23 mg/L and appeared to be related to water colour. It is likely that the elevated aluminum concentrations observed during periods of high flow and water colour are due to increased loading of organically bound aluminum.

Woodland - 00NB01AR0014

The water quality station at Woodland is situated on the United States side of the river approximately 200 meters below the point of Woodland Mill effluent discharge. At this point, river morphometry prevents complete mixing of the effluent with river water and thus provides a good indication of pulp mill effluent chemistry. The highly variable nature of water quality at this station is a function of both the mill effluent load and river discharge rate. Tables 5, 7 and 9 present the physical parameter, major ion and heavy metal data respectively.

The temperature of the St. Croix River at Woodland is controlled by the effluent rather than ambient air temperature. Thus late fall and winter temperatures range from 11.8 to 16°C while mid-summer values reached a maximum of 30.3°C. Dissolved oxygen concentrations are highly variable with saturation values ranging from 68 to 107%. The observed saturation will depend on both the oxygen demand of the effluent after secondary treatment and the degree of dilution by the river water. As would be expected water colour is extremely high (800 - 1600 Hazen Units) due to high concentrations of dissolved organic matter and black liquor in the treated effluent.

The water at Woodland is nearly two orders of magnitude more concentrated than at Kellyland, having specific conductance values ranging from 1240 uS/cm to 2570 uS/cm. The minimum value of 1240 was

observed during September, a period when the Georgia-Pacific Kraft Mill has a temporary shutdown (Howell, 1984). The major ion chemistry at Woodland is dominated by sodium and chloride ions which are used extensively in the Kraft process. (Figure 3) This explains observed concentrations of sodium and chloride being two orders of magnitude greater than those at Kellyland. The other major ions are to a lesser extent found in the mill effluent and thus are also elevated relative to the background concentrations. Potassium concentrations are elevated one to two orders of magnitude while sulphate and bicarbonate concentrations are approximately one order of magnitude greater than background levels. Magnesium and calcium concentrations range from 5 to 10 times greater than values observed at Kellyland.

Mercury concentrations were always at the detection limit while values near to detection were observed for copper, lead and cadmium. Chromium concentrations ranged from 0.004 to 0.07 mg/L exceeding the 0.05 mg/L drinking water guideline on two occasions. Hexavalent chromium salts are often used in the paper industry which may explain the elevated chromium concentrations observed at Woodland (McNeely et al., 1979). Iron concentrations are slightly higher than background levels (0.40 - 0.87 mg/L) while manganese concentrations have been elevated significantly having a range of 0.37 to 2.5 mg/L. Aluminum concentrations are from 1 to 2 orders of magnitude greater than those found at Kellyland, having a range of 1.1 to 5.6 mg/L. These values are likely the result of the use of alum, $(Al_2 (SO_4)_3 \cdot 18 H_2O)$ in the treatment of the fresh process water at the

Georgia-Pacific Pulp Mill. Although these values all exceed the 0.100 mg/L tentative limit (IJC, 1977) proposed for the protection of aquatic biota, the highly organic nature of the effluent would suggest that much of the aluminum is bound to organic matter and therefore not readily available to aquatic organisms.

Baring

At Baring, approximately 8 km downstream from Woodland, water samples are collected from three stations situated across the St. Croix River. These stations are located near to the United States shore, mid-river and near to the Canadian shore and are intended to illustrate the downstream dispersion of the Woodland effluent. The existence of an effluent plume on the United States side of the river has been well documented in previous reports (M.S. Report 1980, M.S. Report 1981, Howell & Lockerbie, 1983) and thus will not be addressed in this report. The physical parameter, major ion and heavy metal data for all three stations are presented in Tables 10 to 12. However the short discussion on water quality at Baring will focus only on data from the mid-river (00NB01AR0018) station.

Water temperatures at Baring closely paralleled those observed at the background station, showing no significant effect of the input of warm effluent water, at Woodland. Dissolved oxygen saturation was high on all sampling dates, ranging from 89 to 103%. The lowest percent saturations were observed during the summer and fall with the minimum value being recorded during a period of high flow and high water colour on June 6. Water colours ranged from 25 to 80 Hazen Units and with one exception, were similar to values observed at Kellyland. On November 1, Baring water colour was 80 Hazen Units, compared to a value of 10 Hazen Units for Kellyland. This may be explained by lack of dilution of highly coloured Pulp Mill effluent (Table 5) during low flow conditions

(Table 3).

Specific conductances at Baring ranged from 46 to 106 uS/cm and are consistently greater than values observed at Kellyland. The maximum value was recorded on November 1, 1983, again indicating the effect of reduced dilution of effluent during low flow conditions. Major ion concentrations at Baring are highly variable with ionic dominance being a function of the relative rates of river discharge and effluent loading. Sodium and chloride were often dominant, having ranges of .147 to .595 ueq/L and .093 to .400 ueq/L respectively. Although sodium was generally the dominant cation, calcium became dominant during several high discharge samplings. This shift reflects a return to ionic dominance characteristic of the St. Croix River in pristine conditions. This shift back to pristine conditions is not as obvious for the anions, as Cl^-, $SO_4^=$ and HCO_3^- concentrations are all affected by the waste effluent. However, HCO_3^- tends to dominate the anions during periods of high flow or low effluent discharge. (Figure 4)

As would be expected, concentrations of heavy metals which were generally below or near to detection at both Kellyland and Woodland were also below detection at Baring. This includes copper, lead, cadmium and mercury. Although chromium values were generally higher than values observed at Kellyland, they were below the 0.05 ueq/L water quality guideline on all occasions. Iron, manganese and aluminum values at Baring were similar to values observed at Kellyland.

Milltown

As was the case at Baring, the WQB monitoring program included the regular monitoring of three stations located at Milltown. These stations were situated near to the United States and Canadian shores and at mid-river.

Past reports have documented and discussed the fact that the horizontal inhomogeneity observed at Baring is not found 6 km downstream at Milltown. Although physical parameters, major ion and heavy metal data from all three Milltown stations will be presented (Table 13 to 15), only data from the mid-river station (00NB01AR0001) at Milltown will be discussed.

As expected water temperature at Milltown was similar to that observed at Kellyland and Baring having a range of 0.5°C to 21.6°C. Dissolved oxygen saturations ranged from 79 to 105% with the lowest values observed during the summer months. The high oxygen demand of the pulp mill effluent has in the past resulted in reduced summer oxygen concentrations at Milltown (Howell & Lockerbie, 1983b; Howell, 1984). In an attempt to re-establish Atlantic salmon in the St. Croix River a dissolved oxygen objective of 60% saturation has been set and was complied with on all seven sampling occasions during the 1983/84 period. Daily dissolved oxygen data from the USGS AWQM at Milltown, also complied with the objective on all occasions during the critical summer period. However, as equipment malfunction resulted in

considerable missing data, the occurrance of oxygen concentrations below the objective is still a possibility during periods of low flow. Water colour ranged from 30 to 100 Hazen Units and was either equal to or slightly greater than values observed at the Baring mid-river station. This would support the contention that the effluent plume is differentiated from the mid-river water mass at Baring but well mixed at Milltown.

Specific conductance ranged from 46 uS/cm to 138 uS/cm and exhibited the same pattern as that observed at Baring. Sodium dominated the cations on all occasions while the dominant anion varied between Cl^- and HCO_3^- depending on discharge rate (Figure 5). Na^+ and Cl^- concentrations were approximately 4 to 5 times greater than the background levels with ranges of .247 to .870 ueq/L and .129 to .620 ueq/L respectively. Sulphate, bicarbonate and potassium values were elevated by a factor of approximately 2 while calcium and magnesium levels were nearly identical to the levels observed at Kellyland.

Concentrations of copper, lead, cadmium and mercury at Milltown were at or near to detection limit on all occasions. As would be expected, aluminum and cadmium concentrations were generally greater than background levels but very near to values observed at Baring. Both iron and manganese concentrations were near to levels observed at Kellyland.

REFERENCES

Howell, G.D. 1984. The Relationship of the Water Quality of the St. Croix River to Pulp Mill Effluent Discharge. Water Quality Branch, Atlantic Region. Inland Waters Directorate (IWD-AR-WQB-84-59) March 1984. 28 p.

Howell, G.D. and D.M. Lockerbie, 1983. 1982/83 St. Croix River Water Quality Report. Water Quality Branch, Atlantic Region, Inland Waters Directorate (IWD-AR-WQB-83-49) October 1983. 47 p.

Howell, G.D. and D.M. Lockerbie, 1983b. St. Croix River Water Quality During the Years 1965-81. Water Quality Branch, Atlantic Region, Inland Waters Directorate (IWD-AR-WQB-83-50). October 1983. 44 p.

International Joint Commission, 1977. New and Revised Specific Water Quality Objectives. Vol. II. Great Lakes Water Quality Board Report.

McNeely, R.N., V.P. Neimanis and L. Dwyer, 1979. Water Quality Sourcebook, Inland Waters Directorate, Ottawa, Canada.

MS. Report, 1980. Report on Water Quality Branch Study of Saint Croix River 1979/80. Water Quality Branch, Atlantic Region, Inland Waters Directorate. January 1980. 44 p.

MS. Report, 1981. Report on Saint Croix River Water Quality 1980. Water Quality Branch, Atlantic Region. Inland Waters Directorate

(IWD-AR-WQB-17). April 1981. 97 p.

W.Q.B. 1983. NAQUADAT Dictionary of Parameter Codes. Water Quality Branch, Inland Waters Directorate, 318 p.

W.Q.B. 1983. Sampling for Water Quality. Water Quality Branch, Inland Waters Directorate, 55 p.

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TABLE 1: NAQUADAT Numbers and Site Descriptions of the Selected Sampling Stations on the Saint Croix River

NAQUADAT Numbers	Site Description
00NB01AR0013	Saint Croix River at Kellyland
00NB01AR0014	Saint Croix River, 200 m below Woodland Mill on the U.S. side of the river
00NB01AR0017	Saint Croix River at Baring RR Bridge - U.S. side
00NB01AR0018	Saint Croix River at Baring RR Bridge - Mid-river
00NB01AR0019	Saint Croix River at Baring RR Bridge - Canadian side
00NB01AR0020	Saint Croix River at Milltown Hwy Bridge - U.S. side
00NB01AR0001	Saint Croix River at Milltown Hwy Bridge - Mid-river
00NB01AR0021	Saint Croix River at Milltown Hwy Bridge - Canadian side

TABLE 2: Dates on which the St. Croix River stations were sampled and the corresponding river discharge

Sampling Dates	River Discharge* CFS
09-06-83	3800
16-08-83	2680
13-09-83	1050
01-11-83	1020
13-12-83	3850
07-02-84	3060
22-03-84	No data

* Discharge at Baring USGS gauge

TABLE 3: A list of parameters, parameter codes and their detection limits

Parameters	NAQUADAT Parameter Code	Detection Limits
Temperature	02065S	-
Dissolved Oxygen (meter)	08102F	-
Dissolved Oxygen (Winkler)	08101F	10 ug/L
Specific Conductance	02042F	2 uS/cm
pH	10301F	-
Specific Conductance	02041L	0.2 uS/cm
pH	10301L	-
Colour	02011L	-
Turbidity	02073L	0.0
Extractable Iron	26304P	50. ug/L
Extractable Manganese	25304P	10. ug/L
Extractable Copper	29305P	0.1 ug/L
Extractable Lead	82303P	1. ug/L
Extractable Aluminum	13305P	2. ug/L
Extractable Mercury	80315P	.02 ug/L
Extractable Cadmium	48302P	1. ug/L
Extractable Chromium	24303P	0.5 ug/L
Sodium	11103L	0.1 mg/L
Calcium	11103L	.04 mg/L
Potassium	19103L	0.1 mg/L
Magnesium	12107L	.005 mg/L
Chloride	17201L	0.1 mg/L
Sulfate	16304L	1.0 mg/L
Total Alkalinity	10101L	0.5 mg/L

TABLE 4: Measurements of temperature, dissolved oxygen, specific conductance, pH, water colour and total alkalinity on seven dates for the St. Croix River at Kellyland (Station No. 00NB01AR0013)

Date	Temp oC	Oxygen mg/L	Oxygen % sat	Sp. Cond. uS/cm	pH	Colour (H.U.)	Alkalinity mgCaCO3/L
09-06-83	16.2	9.5	100	31	6.5	50	6.4
16-08-83	20.9	-	-	15	6.4	30	6.6
12-09-83	21.8	8.5	99	29	6.9	20	7.0
01-11-83	6.5	11.8	101	24	6.9	10	6.2
13-12-83	0.5	14.2	101	33	6.0	60	5.7
06-02-84	0.6	13.7	98	22	6.6	25	6.5
21-03-84	1.0	14.0	102	30	6.6	30	6.7

TABLE 5: Measurement of Temperature, Dissolved Oxygen, Specific Conductance, pH, Water Colour and Total Alkalinity for the St. Croix River at Woodland (Station No. 00NB01AR0014)

Date	Temp	Oxygen		Sp Cond.	pH	Colour	Alkalinity
	oC	mg/L	% sat	uS/cm		(H.U.)	
09-06-83	21.5	-	-	-	7.3	800	173
16-08-83	30.3	5.1	68	1840	7.4	1200	272
12-09-83	24.0	7.8	95	1240	7.1	800	151
01-11-83	23.0	7.2	86	2420	7.0	1600	281
13-12-83	15.0	10.4	96	2200	7.4	1400	303
06-02-84	16.5	10.1	107	2570	7.4	1200	338
21-03-84	11.8	10.8	103	2130	7.7	1200	294

TABLE 6: Major Ion equivalent concentrations (for the St. Croix River at Kellyland (Station No. 00NB01AR0013)

Date	Ca	Mg	K	Na	Cl	SO4	HCO3
				meq/L			
09-06-83	.150	.037	.005	.052	.037	.079	.128
16-08-83	.159	.047	.005	.069	.036	.073	.131
13-09-83	.159	.046	.012	.056	.042	.079	.139
01-11-83	.149	.045	.008	.057	.048	.075	.124
13-12-83	.179	.060	.005	.065	.062	.104	.114
07-02-84	.169	.053	.007	.060	.048	.087	.129
22-03-84	.174	.052	.007	.056	.048	.072	.139

TABLE 7: Major ion equivalent concentration for the St. Croix River 200 m below Woodland Mill on the U.S.A. side of the river (Station No. 00NB01AR0014)

Date	Ca	Mg	K	Na	Cl	SO4	HCO3
				meq/L			
09-06-83	1.3	.197	.230	5.3	5.9	2.4	3.5
16-08-83	1.9	.320	.409	17.8	10.1	3.2	5.4
13-09-83	1.2	.205	.358	9.6	5.4	3.0	3.0
01-11-83	2.7	.345	.620	20.4	12.9	4.8	5.6
13-12-83	2.9	.386	.639	18.7	11.3	4.9	6.1
07-02-84	4.1	.436	.613	21.7	13.5	6.4	6.8
22-03-84	2.8	.444	.626	17.8	11.5	5.0	5.9

TABLE 8: Heavy Metal Concentrations for the St. Croix River at Kellyland (Station No. 00NB01AR0013)

Date	Fe	Mn	Cu	Pb	Cd	Al	Cr	Hg
				mg/L				ug/L
09-06-83	.18	.03	L.002	L.002	L.001	.23	.001	L.02
16-08-83	.15	.03	.004	L.002	L.001	.03	.0032	L.02
13-09-83	.12	-	.005	.002	-	.02	L.0005	L.02
01-11-83	.18	-	-	L.002	-	-	-	L.02
13-12-83	.18	.01	L.002	L.002	L.001	.11	L.0005	L.02
07-02-84	.10	.01	L.002	L.002	L.001	.04	L.0005	L.02
22-03-84	.10	.01	L.002	L.002	L.001	.06	.0006	L.02

TABLE 9: Heavy Metal Concentrations for the St. Croix River, 200 m below the Woodland Mill on the U.S.A. side (Station No. 00NB01AR0014)

Date	Fe	Mn	Cu	Pb	Cd	Al	Cr	Hg
			mg/L					ug/L
09-06-83	.64	.37	L.002	L.002	L.001	1.1	.004	L.02
16-08-83	.64	1.6	.002	.005	.001	3.6	.013	L.02
13-09-83	.40	.87	.004	.004	.001	3.1	.016	L.02
01-11-83	.87	2.5	.003	.004	.002	5.6	.06	L.02
13-12-83	.86	1.5	.002	.006	.001	3.0	.024	L.02
07-02-84	.53	1.7	L.002	.006	L.001	2.5	.070	L.02
22-03-84	.47	1.9	L.002	.003	.002	2.0	.020	L.02

TABLE 10. Measurements of Temperature, Dissolved Oxygen, Specific Conductance, pH, Water Colour and Total Alkalinity on seven dates at three stations located at Baring

Date	Station	Temp oC	Oxygen mg/L	Oxygen % sat	Sp Cond uS/cm	pH Lab	Colour (H.U.)	Alk mgCaCO3/L
09-06-83	U.S.	15.8	8.4	88	89	6.8	100	12.6
	Mid-river	15.6	8.6	89	47	6.7	60	7.4
	Canada	15.5	8.6	89	41	6.6	50	6.3
16-08-83	U.S.	23.3	7.2	86	108	6.6	80	14.4
	Mid-river	23.2	8.0	96	48	6.3	30	9.0
	Canada	22.6	8.0	95	42	6.4	30	8.2
13-09-83	U.S.	21.0	7.5	86	73	6.5	45	12.3
	Mid-river	21.0	8.2	94	48	6.5	25	8.7
	Canada	21.0	8.2	94	44	6.4	25	8.6
01-11-83	U.S.	8.0	10.2	89	200	6.3	120	2.3
	Mid-river	7.7	11.4	99	106	6.2	65	13.3
	Canada	7.5	11.6	100	85	6.2	55	11.9
13-12-83	U.S.	1.3	13.7	100	95	7.2	100	-
	Mid-river	1.0	14.0	102	50	5.9	80	6.6
	Canada	1.0	14.0	102	38	5.9	70	6.8
07-02-84	U.S.	0.5	13.6	97	118	6.8	65	14.9
	Mid-river	0.5	13.6	97	57	6.8	35	8.7
	Canada	0.0	13.7	97	47	6.7	35	8.0
22-03-84	U.S.	1.5	14.0	103	92	6.7	60	13.3
	Mid-river	1.0	14.2	103	46	6.6	40	8.1
	Canada	1.0			42	6.6	40	7.6

TABLE 11: Major Ion equivalent concentrations for the St. Croix River at three stations located at Baring

Date	Station	Ca	Mg	K	Na	Cl	SO4	HCO3
				meq/L				
09-06-83	U.S.	.164	.056	.015	.439	.206	.177	.252
	Mid-river	.149	.041	.008	.147	.093	.099	.148
	Canada	.176	.037	.008	.126	.071	.083	.126
16-08-83	U.S.	.219	.056	.025	.604	.341	.176	.287
	Mid-river	.179	.051	.015	.187	.126	.089	.179
	Canada	.169	.049	.007	.160	.101	.104	.163
13-09-83	U.S.	.189	.055	.017	.391	.205	.170	.245
	Mid-river	.169	.051	.015	.200	.118	.114	.173
	Canada	.159	.051	.015	.178	.107	.108	.171
01-11-83	U.S.	.299	.069	.038	1.34	.874	.351	.460
	Mid-river	.209	.056	.020	.595	.400	.208	.266
	Canada	.199	.054	.017	.478	.293	.170	.238
13-12-83	U.S.	.254	.069	.031	.566	.355	.229	-
	Mid-river	.189	.064	.015	.221	.155	.131	.132
	Canada	.179	.065	.012	.169	.121	.124	.136
07-02-84	U.S.	.314	.063	.023	.635	.479	.266	.297
	Mid-river	.189	.051	.010	.174	.160	.135	.173
	Canada	.174	.051	.010	.156	.124	.110	.160
22-03-84	U.S.	.239	.060	.023	.491	.341	.204	.265
	Mid-river	.179	.052	.012	.165	.124	.104	.161
	Canada	.174	.048	.010	.143	.104	.099	.151

TABLE 12: Heavy Metal Concentrations for the St. Croix River, at three stations located at Baring

Date	Station	Fe	Mn	Cu	Pb	Cd	Al	Cr	Hg
				mg/L					ug/L
09-06-83	U.S.	.23	.05	L.002	L.002	L.001	.14	.0008	L.02
	Mid-river	.19	.03	L.002	L.002	L.001	.11	.001	L.02
	Canada	.19	.02	L.002	L.002	L.001	.10	L.0005	L.02
16-08-83	U.S.	.23	.08	L.002	L.002	L.001	.10	.0009	L.02
	Mid-river	.19	.05	L.002	L.002	L.001	.050	L.0005	L.02
	Canada	.19	.05	L.002	L.002	L.001	.035	L.0005	L.02
13-09-83	U.S.	.18	.05	.004	.002	L.001	.08	.0006	L.02
	Mid-river	.18	.04	.006	.002	L.001	.040	L.0005	L.02
	Canada	.17	.04	.005	L.002	L.001	.042	L.0005	L.02
01-11-83	U.S.	.27	.15	L.002	.003	L.001	.23	.0043	L.02
	Mid-river	.24	.08	L.002	L.002	.001	.15	.0021	L.02
	Canada	.23	.06	L.002	L.002	L.001	.11	.0018	L.02
13-12-83	U.S.	.24	.07	L.002	L.002	L.001	.21	.0031	L.02
	Mid-river	.23	.03	L.002	L.002	L.001	.14	.0007	L.02
	Canada	.22	.03	L.002	L.002	L.001	.14	L.0005	L.02
07-02-84	U.S.	.14	.07	L.002	L.002	L.001	.12	.0024	L.02
	Mid-river	.11	.03	L.002	L.002	L.001	.075	.0009	L.02
	Canada	.11	.03	L.002	.002	L.001	.080	.0007	L.02
22-03-84	U.S.	.10	.02	L.002	L.002	L.001	.065	.0009	L.02
	Mid-river	.10	.02	L.002	L.002	L.001	.070	L.0005	L.02
	Canada	.10	.05	L.002	L.002	L.001	.11	L.0005	L.02

TABLE 13: Measurements of Temperature, Dissolved Oxygen, Specific Conductance, pH, Water Color and Total Alkalinity on Seven dates at three stations located at Milltown

Date	Station	Temp oC	Oxygen mg/L	Oxygen % sat	Sp Cond uS/cm	pH Lab	Colour (H.U.)	Alkalinity mg CaCO3/L
09-06-83	U.S.	15.7	8.0	83	63	6.7	80	10.0
	Mid-river	15.9	8.4	88	58	6.8	80	12.4
	Canada	15.9	8.0	84	52	6.6	70	8.1
16-08-83	U.S.	22.0	6.7	79	70	6.5	55	11.2
	Mid-river	21.6	6.8	79	70	6.5	50	11.2
	Canada	21.8	6.8	79	61	6.5	40	10.4
13-09-83	U.S.	21.5	7.6	88	56	6.4	35	10.0
	Mid-river	21.5	7.7	89	55	6.9	30	9.9
	Canada	21.7	7.6	89	55	6.4	35	9.4
01-11-83	U.S.	7.0	10.3	88	138	6.8	100	16.5
	Mid-river	7.3	10.4	89	138	7.0	100	16.7
	Canada	7.3	10.5	90	127	6.9	90	16.1
13-12-83	U.S.	0.5	13.8	99	68	6.0	80	8.1
	Mid-river	0.5	13.4	96	63	6.8	45	9.8
	Canada	0.5	13.8	99	53	5.9	80	6.8
07-02-84	U.S.	0.5	12.8	92	68	6.7	40	9.6
	Mid-river	0.5	13.4	96	63	6.8	45	9.8
	Canada	0.5	13.2	94	49	6.6	35	7.2
22-03-84	U.S.	0.5	14.2	103	66	6.7	50	10.3
	Mid-river	1.4	14.3	105	53	6.7	40	9.6
	Canada	1.2	14.2	104	52	6.7	40	8.8

TABLE 14: Major Ion Equivalent Concentrations for the St. Croix River at three stations located at Milltown

Date	Station	Ca	Mg	K	Na	Cl	SO4	HCO3
09-06-83	U.S.	.125	.041	.013	.278	.143	.131	.200
	Mid-river	.139	.049	.010	.247	.129	.120	.247
	Canada	.125	.042	.008	.187	.096	.104	.162
16-08-83	U.S.	.194	.054	.015	.378	.214	.139	.223
	Mid-river	.199	.054	.017	.365	.211	.124	.223
	Canada	.194	.054	.012	.291	.169	.124	.207
13-09-83	U.S.	.179	.052	.020	.269	.146	.129	.199
	Mid-river	.179	.052	.015	.256	.143	.129	.197
	Canada	.169	.051	.017	.052	.141	.129	.187
01-11-83	U.S.	.249	.063	.028	.913	.648	.295	.330
	Mid-river	.249	.063	.028	.870	.620	.270	.334
	Canada	.249	.065	.025	.800	.592	.257	.322
13-12-83	U.S.	.209	.065	.020	.330	.228	.162	.162
	Mid-river	.199	.065	.020	.287	.200	.156	.152
	Canada	.194	.065	.015	.213	.149	.131	.136
07-02-84	U.S.	.239	.057	.015	.326	.214	.156	.191
	Mid-river	.239	.059	.015	.334	.231	.164	.195
	Canada	.204	.057	.010	.174	.139	.127	.143
22-03-84	U.S.	.204	.058	.015	.291	.217	.145	.205
	Mid-river	.199	.056	.015	.261	.189	.137	.191
	Canada	.189	.056	.012	.204	.149	.120	.176

TABLE 15: Heavy Metal Concentrations for the St. Croix River at three stations located at Milltown

Date	Station	Fe	Mn	Cu	Pb	Cd	Al	Cr	Hg
				mg/L					ug/L
09-06-83	U.S.	.21	.04	L.002	.002	.001	.14	.002	L.02
	Mid-river	.17	.04	L.002	L.002	L.001	.098	.0008	L.02
	Canada	.21	.04	L.002	L.002	L.001	.10	.002	L.02
16-08-83	U.S.	.21	.06	L.002	L.002	L.001	.067	L.0005	L.02
	Mid-river	.17	.04	.005	.002	L.001	.067	.0005	L.02
	Canada	.21	.06	L.002	.002	L.001	.060	.0006	L.02
13-09-83	U.S.	.17	.04	.005	.002	L.001	.055	.0005	L.02
	Mid-river	.17	.04	.005	.002	L.001	.065	.0006	L.02
	Canada	.18	.04	.004	.002	L.001	.060	.0005	L.02
01-11-83	U.S.	.29	.09	L.002	L.002	L.001	.14	.0031	L.02
	Mid-river	.29	.09	L.002	.002	L.001	.15	.0033	L.02
	Canada	.29	.08	L.002	L.002	L.001	.14	.0026	L.02
13-12-83	U.S.	.23	.04	L.002	L.002	L.001	.16	.0007	L.02
	Mid-river	.24	.04	L.002	L.002	L.001	.17	.0007	L.02
	Canada	.24	.04	L.002	L.002	L.001	.17	.0005	L.02
07-02-84	U.S.	.17	.05	L.002	L.002	L.001	.075	.0012	L.02
	Mid-river	.13	.04	L.002	L.002	L.001	.075	.0015	L.02
	Canada	.17	.04	L.002	L.002	L.001	.075	.0006	L.02
22-03-84	U.S.	.14	.04	L.002	L.002	L.001	.090	.0006	L.02
	Mid-river	.10	.04	L.002	L.002	L.001	.085	L.0005	L.02
	Canada	.10	.03	L.002	L.002	L.001	.085	L.0005	L.02

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Figure 5 Ionic proportions at Milltown (mid-river) for two dates exhibiting different mean daily discharge

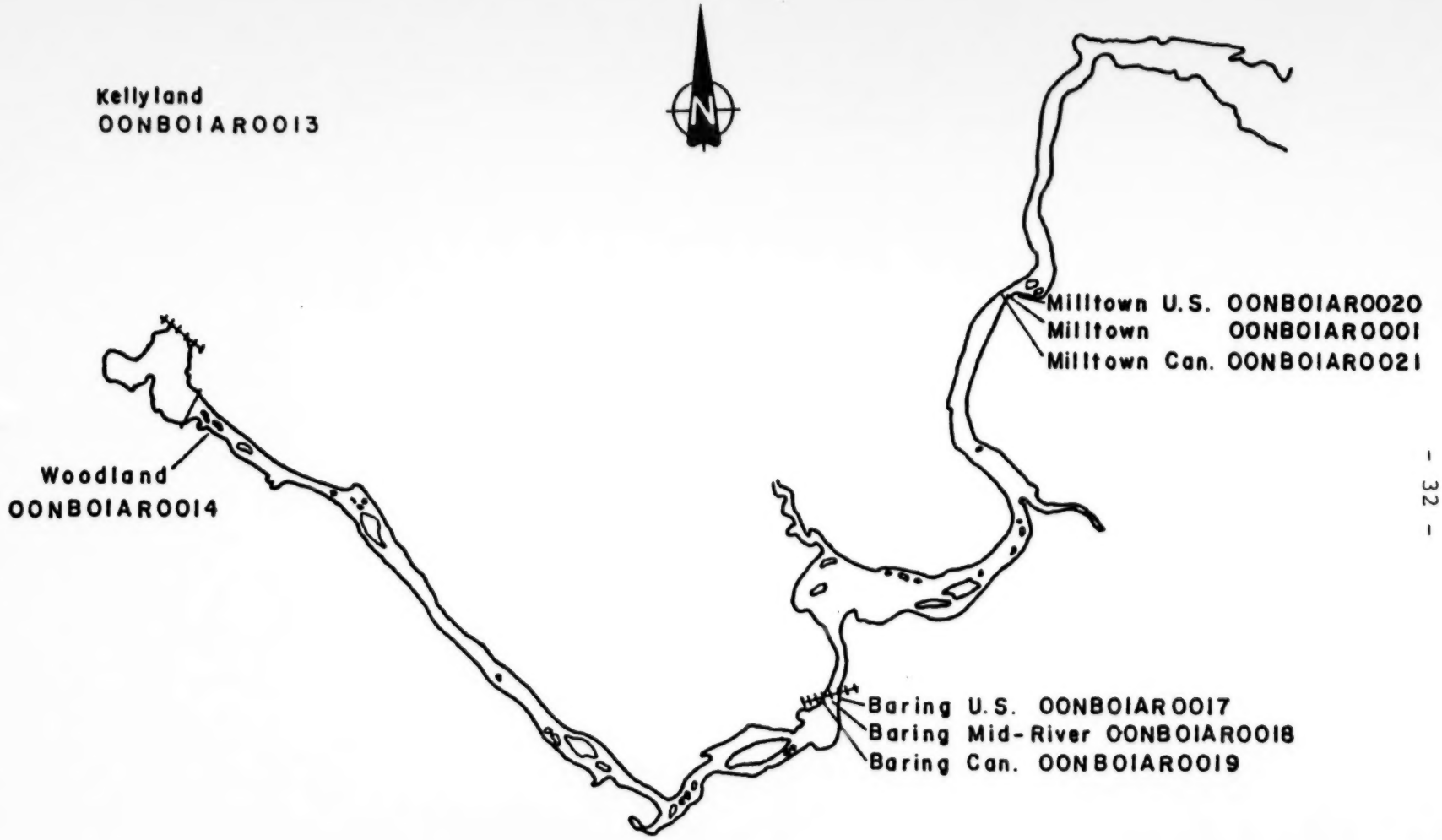

Fig. 1 Map of Study Area

KELLYLAND

JUNE
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NOV 1,1983
FLOW=1020 CFS

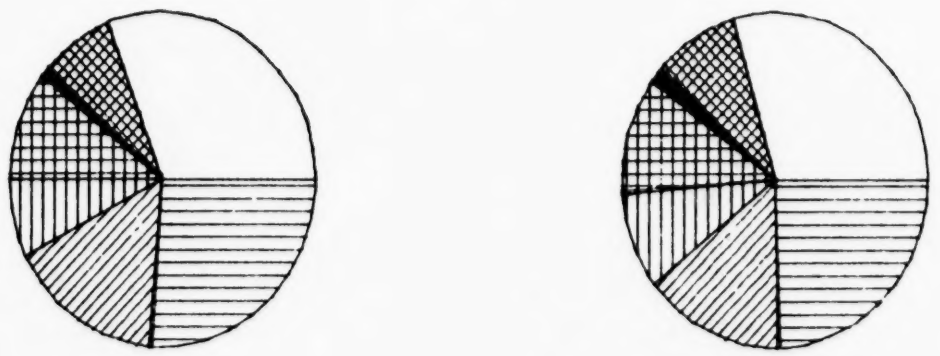

Figure 2

WOODLAND

05-SEP-84 9:42 P

JUNE 9,1983
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NOV 1,1983
FLOW=1020 CFS

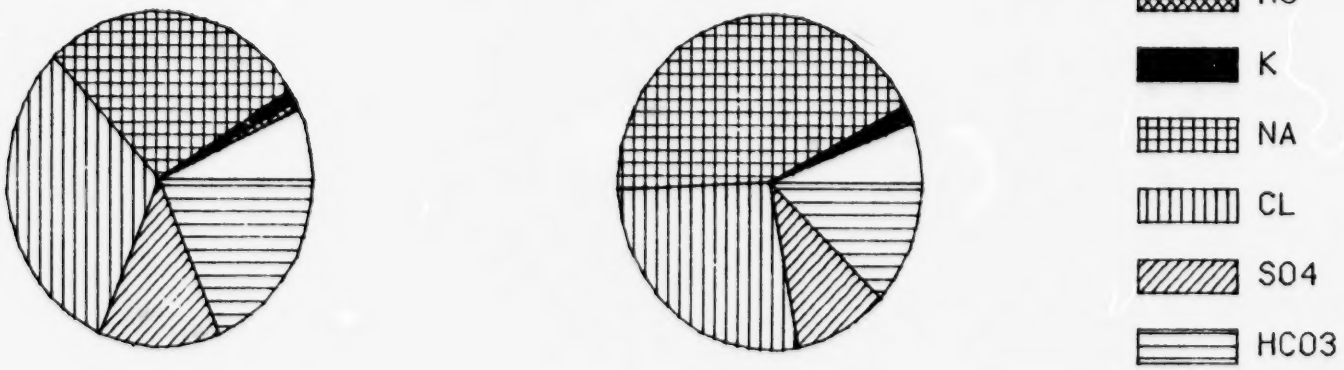

Figure 3

BARING

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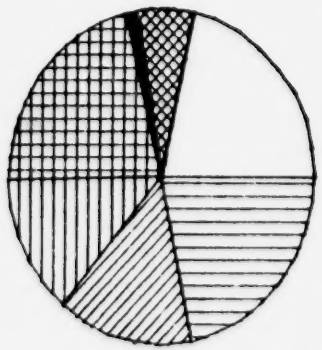
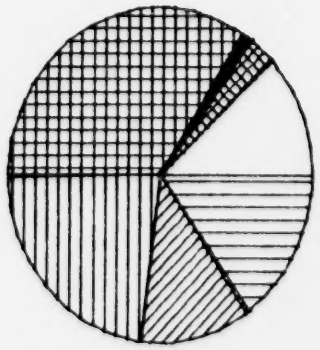
NOV 1,1983
FLOW=1020 CFS





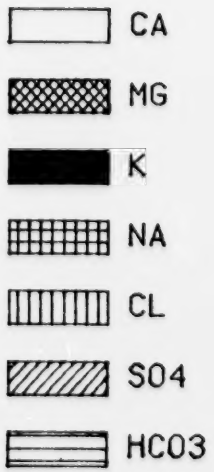


Figure 4

MILLTOWN

JUNE 9,1983
FLOW=3800 CFS

NOV 1,1983
FLOW=1020 CFS

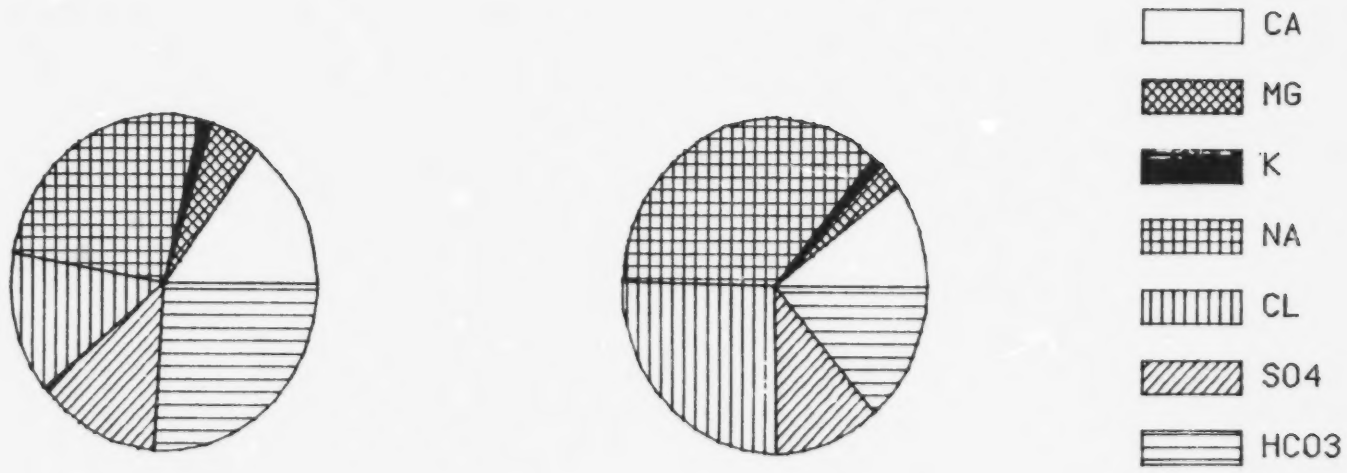


Figure 5